# *Action Learning Project:*

## Using an inquiry-based practical class to enhance student understanding

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## Contents

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## Statement of Problem and Context

How can I encourage students to grasp the overall function of a physiological system while still preserving enough detail to understand the cellular mechanisms that underlie systems physiology?

The problem in teaching physiology is the difficulties students face integrating their factual knowledge and knowledge of concepts into a construct of whole system function, and hence whole body function. Students lack the ability to integrate their knowledge into a practical understanding of body function. An example of this may be their inability to consider the blood flow, distribution, and pressure characteristics of the cardiovascular system to accurately predict the responses of the body to a challenge such as exercise. During exercise there is a demand for greater blood flow to the exercising muscles, but a need for the body to maintain arterial blood pressure so the body responds in a predictable manner. The ability to accurately predict the response of the body reflects a fundamental understanding of the physiological mechanisms that underlie cardiovascular function.

The teaching of physiology has traditionally included a variety of delivery modes with tutorials and practical laboratory classes contributing a large component of many courses. These classes are seen as the opportunity for students to test their understanding of concepts and to develop critical thinking skills. However, in laboratory classes students often display either a lack of understanding of physiological concepts or have misconceptions of fundamental knowledge. Thus, the students are unable to draw conclusions based on the experiments they are performing. These misconceptions may be based on misunderstanding of prior knowledge but they may also reflect some of the fundamental misinformation of body function that is portrayed in the media, this is especially evident with regard to nutrition and energy balance. In addition students often appear reluctant to consider the implications of their experimental results, even when the results are contrary to their expectations, often simply assuming they have done "something wrong" so their data must be incorrect rather than their expectations.

The goal of any educational intervention should be to improve the learning outcome for students. In this case the intervention is focused improving the outcome of a laboratory class that specifically aims to improve the critical thinking skills of the students, enabling them to recognize their own misconceptions and to judge the information that is presented to them, both within their university courses but also from the general media. As this intervention is to take place in the context of a professional program, the improvement of these skills also aims to enhance the development of attributes the students will need to work as professionals after graduation.

## *Context*

*Course & Topic*

The course to be used for this educational intervention is a 2$^{nd}$ level physiology course offered by the School of Biomedical Sciences. The course has a strong emphasis on teaching laboratory classes, with almost as many hours allocated to laboratory classes as to lectures. The intervention will take place in one of the laboratory classes, the topic of this class is Metabolism: Nutrition and Energy Balance. The ~3 hour class is run in conjunction with a 6 lecture series on the Physiology of the Gastrointestinal system and is linked to a subsequent laboratory class, taught in the following week, which focuses on Metabolic Rate. These two classes are taught on four occasions during the semester to one quarter of the cohort each time, repeated each fortnight.

This topic, nutrition and energy balance, is one which generates a lot of interest amongst the students. They relate to it personally, in that many of them are aware of their own diet and exercise regimens, but also they relate to it professionally, they recognize that they will be dealing with the consequences of diet and energy imbalance in their clients, and that they will need to be able to address these issues and formulate appropriate management strategies for their clients.

*Cohort*

The cohort that will be evaluated is a subset of the 2nd year Undergraduate Occupational Therapy and Speech Pathology, and 1st year Postgraduate Coursework Masters Occupational Therapy and Speech Pathology students. These students completed a Physiology course in semester 1, but prior to that their background in biological sciences has generally been quite limited, with some students having not studied any biology since their early years of high school. Traditionally these students have struggled with the conceptual nature of physiology, have difficulty translating course content into an understanding of system and body function and display misconceptions in their knowledge.

## Literature review

The constructivist model of learning implies that the learner is involved in ongoing hypothesis-testing based on their current knowledge and thought patterns. It suggests that learning takes place in the context of prior knowledge and attitudes of the learner which need to be challenged so that the learner reconsiders established ideas and expands their understanding to develop an improved model (GCHE course notes, Module 2, 2004). Shiland (1999) suggests that there are specific implications of the constructivist model for laboratory classes; that classes should aim to increase the students' cognitive activity, identify their preconceptions and misconceptions, challenge these ideas and allow the students to formulate their ideas through discussion and application of their knowledge to situations. However, many laboratory classes fail to achieve these aims, often the extent of the students' participation is limited to performance of experiments and data collection, while the tutor directs and leads discussion on the theory and concepts underlying the experiments, failing to even consider the students prior knowledge. These problems can lead to students being disillusioned with the laboratory classes resulting in poor learning outcomes (DiPasquale, et al 2003).

Laboratory classes provide teachers with an ideal opportunity to interact with our students in a small group environment. Modell, et al (2000) describe how undergraduate students often have fundamental misconceptions in their “mental models” when they enter a laboratory class, and that these misconceptions may or may not be corrected by the class. The interaction we have in laboratory classes affords us an opportunity to gauge the deeper understanding of our students, identifying their preconceptions and misconceptions by being able to engage in question and answer sessions with the students on an individual and group level (Micheal, et al 2002). This serves to allow us to identify general misconceptions held by the student group, allowing us, with reflection, to improve the design of our classes to address these problems. But further than this, we also have the opportunity to bring the misconceptions to the students’ attention, encouraging them to reflect on their knowledge to encourage them to develop self-awareness (Modell, et al 2000).

In order for our laboratory classes to be effective teaching tools it is necessary to engage the students in the learning process, to encourage their active participation. The use of active learning strategies should improve the students’ achievements, their attitudes, their motivation and their ability to accurately predict outcomes (Wilke, 2003). But encouraging active learning does not just mean that students should simply be given more to do in the class, it actually means that the students should be given more opportunity to consider the implications of what they are doing (Domin, 1999a). Modell. et al, (2000) suggest that the critical factor in promoting learning in laboratory classes is the way in which students participate, that is “the important component is not ‘active’, but active learning”.

*Laboratory instruction systems*

There are a number of alternate laboratory teaching systems that have been developed that attempt to address some of these issues. Domin (1999b) summarises the styles recognized in current practice and briefly discusses the strengths and limitations of each method. While their review separates the laboratory teaching systems into four distinct categories, the reality is that there exists some overlap between the methods. Teaching systems described include the traditional “expository” instruction style, a teacher-oriented approach with pre-determined outcomes that is still widely practiced. Di Pasquale, et al (2003) identified that their students displayed a lack of enthusiasm and frustration with this traditional teacher-oriented laboratory class system of “cookbook” classes, where the students followed step-by-step instructions to achieve a pre-determined goal. This system discourages students from developing analytical and critical thinking skills, and encourages the view of scientific process as steps towards completing a laboratory report, rather than being representative of actual scientific experimentation (DiPasquale, et al 2003; Domin, 1999b).

The inquiry-based laboratory systems are alternatives to this style. Inquiry-based systems require the students to formulate their own procedures to address questions. The extent of inquiry in a class can be varied. The greatest occurs in the open-inquiry model where there is an undetermined outcome such that students identify and formulate the problem, predict the results and design and perform the procedure and investigations. This method gives the students an opportunity to develop higher-order thinking skills in order to engage in the investigation (Domin, 1999b). Reports of this method emphasize that the students display an improvement in independent thinking, in ability to “see the larger picture” and particularly their ability to integrate knowledge both from within the areas of the course and from other courses (DiPasquale, et al 2003). However this method also puts places great demands on the students, such that it is necessary to re-train them by gradually increasing the level of inquiry throughout the course (DiPasquale, et al 2003). This method can also be very demanding of resources and personnel.

The extent of inquiry can also be applied to a lesser degree, where the system used represents a “guided-inquiry” approach, with the instructor guiding the students toward the desired outcome. In this system the students study a particular phenomenon to discover the underlying principles using materials provided, such as group discussions, textbooks and experiments, to reach the pre-determined outcome (Domin, 1999b). Berg, et al (2003) examine the use of an inquiry-based learning environment to improve student learning outcomes, in a direct comparison between a guided-inquiry and expository version of a laboratory experiment. The authors report that the inquiry-based class encouraged the students to be more reflective and positive and thus result in improved learning outcomes (Berg, et al 2003).

Problem-based learning represents another alternative laboratory teaching system. In this system the students are presented with a problem scenario and are required by deduction to create their own procedures, based on their current knowledge and their recognition of areas where their knowledge is lacking, in order to explore and solve the problem (Domin, 1999b; Davies, 2000; McKinley & Stoll, 1994). They are encouraged to determine their own learning needs and objectives, and identify the resources they require to solve the problem (Davies, 2000). They also need to evaluate whether these criteria have been met during their learning processes (Davies, 2000). Students involved in a problem-based laboratory need to apply their conceptual knowledge in order to devise the means of reaching the solution, that is, they need to think about what they are doing and, most importantly, why they are doing it (Domin, 1999b). In doing so this system encourages the development of higher-order cognitive skills (Domin, 1999b). However problem-based learning has some limitations, it is necessary for the students to understand both the process required and the principles involved to enable successful problem solving to occur, this in turn requires the students to be sufficiently motivated to identify their own misconceptions or deficits and correct them (Domin, 1999b).

*Design considerations*

The use of a single laboratory class in a series of classes places design limitations on the intervention, primarily due to the time constraints. Both open-inquiry and problem-based learning systems require considerable introduction of the students to the processes required and therefore make them impractical to implement in a single laboratory class. The guided-inquiry system therefore offers the best solution, in the given time-frame, as a substitute for the current expository class, particularly as it can also contain elements of both open-inquiry and problem-based systems.

One aspect of the students in this cohort that needs to be considered is the fact that they represent a group of students with quite diverse educational backgrounds, particularly among the Masters students. The programs represented select from a broad range of students often derived from the social sciences. The physiology courses (in first and second semester) present them with a considerable challenge, due to the conceptual nature of physiology and the students' limited background in biology, and they reflect that by having varying attitudes to this course based on the prior exposure to the "hard" sciences and their experience in first semester. This aspect needs to be considered because it has been postulated that the alternate types of laboratory instruction systems might have different impacts on students according to their prior attitudes and as such those attitudes may have a significant impact on their learning outcomes (Berg, et al 2003). In a study designed to address this topic Berg, et al (2003) determined the attitudes of the students in a study comparing inquiry and expository-based laboratories by means of a questionnaire. On evaluation they found that while all students benefited from the open-inquiry formats used in their study, the "low position" students particularly benefited from additional input from the instructors. They made particular note that "high position” students readily accepted the challenge of the open-inquiry systems whereas the “low position” students did not do so easily and therefore required more careful introduction to these systems (Berg, et al 2003).

## Educational Intervention Design

### *Intervention*

*Aims*

The aim of this intervention is to identify the misconceptions the students may have, address those misconceptions and allow the students to explore and integrate the information available to them to improve their critical thinking skills. Further, the class should encourage them to develop the skills to appraise the value of nutritional information they are exposed to and to identify the important factors which will influence an individuals’ metabolic needs. Based on prior experience with this topic, the misconceptions I have observed the students display relate to the sources of energy available to the body, the energy requirements of the body and the factors which influence these aspects of metabolism.

*Design*

The method used in this intervention is based on a guided-inquiry system and takes into consideration the constructivist implications for laboratory classes raised by Shiland (1999). The design will aim specifically to markedly increase the students’ reflection on the topics and to increase the active participation of the students by engaging them more in the direction of the process (Wilke, 2003). The class is divided into four components, each discussed in more detail below. The format of the class is as follows:

1. Answer initial questions – individually (15 min)
2. Tutorial – discussion of topics raised, address any misconceptions (30 min)
3. Workshop – group work, looking at energy intake and expenditure (45 min)
4. Discussion – outcome of workshop, re-examine initial questions (30 min)

They will be asked to firstly consider their own knowledge with a short series of open-ended questions. The questions are designed to highlight any misconceptions they may hold and to make them predict the outcome of their investigations into their own energy consumption and requirements.

The students will then be involved in a tutorial discussing the topics highlighted in the questions. It will address the misconceptions that have been raised, discuss the sources of energy in nutrition and the metabolic needs of the body. The tutorial subsequently leads into a small-group workshop that provides an opportunity for them to investigate the energy intake, consumption and expenditure of themselves or a group member. They will review a 24 hour self-reported food consumption and a 24 hour self-reported activity description using the nutritional component and energy expenditure tables provided. It will be necessary for the students to integrate the knowledge gained in the gastrointestinal lectures, their prior physiology lectures and the information presented during the tutorial component of the laboratory to understand the consequences of metabolism, nutrition and energy balance. The outcome of the workshop will be the subject of a general discussion.

Finally they will be asked to return individually to their answers of the original questions, reconsider them in view of the knowledge they have gained during the class and reflect on the misconceptions they may have held prior to the class. Both sets of questions, notes for the tutorial, and workshop notes and questions are presented in a practical book that the students complete during the laboratory class. This can then be used as a resource for future study (see appendix 1).

While it is not my intention to specifically test the pre-held attitudes of the students to this course, I recognize from previous experience that their attitude tends to be slightly negative and as such intend to take particular care when introducing this inquiry-based class to them. The class will be presented on four occasions during the semester with a class size of approximately 42 students. It will be taught solely by me on each occasion, removing the complications that may have arisen if the class was delivered by multiple teachers.

## *Evaluation of the Educational Intervention*

Much of the literature reviewed emphasised the importance of encouraging the students to reflect on the knowledge they have constructed, to give due consideration to problems they are analysing and critically review their thinking. The means to encourage this reflection differs between the studies and of particular interest to me was the use of open-ended questions in assessment by DiPasquale, et al (2003). In evaluating the intervention it was necessary to elicit the extent to which the intervention has influenced the different aspects of student learning outcomes and how far the intervention went in achieving the stated aims.

### *Questionnaire*

The questionnaire (see Appendix 2) was designed to address a number of aspects of the evaluation, to assess the extent to which the students were able to recognize their own misconceptions and to develop the critical thinking skills to judge information presented to them. It was comprised of both closed questions, which allow students to select from a pre-determined set of responses, and open-ended questions, allowing students to individually express their response, drawing on the example given by Bourner, et al (2001). As these interventions took place in the context of a single class I felt that the total number of questions should be restricted to reflect the length of the class and avoid issues of “survey fatigue”.

### *Summative Assessment Results*

The students were formally assessed by short answer (open-ended) and multiple choice questions directly related to this laboratory class in the end of semester examination. The examination questions were designed to test the students’ conceptual understanding of metabolism, asking them to apply their knowledge to an alternative context. The results from these questions is compared to answers to similar questions from the cohorts of the previous year, during which time this class was taught by me in an expository style class without the interventions described above. The overall examination results from each year will be compared with this year so that a comparison of mean and standard deviation between the different cohorts can be made and any necessary correction can be applied.

*Personal observation and reflections*

During the classes I observed and noted aspects such as student misconceptions and their willingness to recognize them, the level of participation of the students and their willingness to reflect on the questions posed at the end of the class.

## Results

### *Questionnaire responses*

This section presents the findings of the questionnaire study along with a commentary on the responses. A total of 75 students responded to the questionnaire, with 17, 11, 19 and 28 responding from each consecutive class. As there were no exceptional circumstances that arose during each consecutive class and the student responses appeared to be similar the results from each class were pooled and treated as a whole. All the students who attended the laboratory class, with the exception of approximately 12 who left early for various reasons, completed the questionnaire. The number of students attending represents only 55% of the total enrolment for this course as the laboratory classes, while strongly recommended, are not compulsory.

The first part of the questionnaire was comprised of three ‘closed’ questions asking the students to select on a scale of 1 – 5 the response which most suited their answer, with 1 representing strongly agree and 5 representing strongly disagree (see appendix 2). These questions were designed to evaluate the central aims of this project, which were to enable students to recognise misconceptions they may hold (question 1), to allow the students to explore and integrate the information available so they can identify the important factors which will influence an individuals' metabolic needs (question 2) and to develop the skills to appraise the value of nutritional information they are exposed to (question 3). The responses to these questions are summarised below.

***Question 1. This workshop helped me to recognise misunderstandings I may have had about nutrition and energy balance***

| Response | Number | Percentage |
|---|---|---|
| 1. Strongly Agree | 13 | 17.3 |
| 2. Agree | 42 | 56 |
| 3. Neutral | 19 | 25.3 |
| 4. Disagree | 1 | 1.3 |
| 5. Strongly disagree | 0 | 0 |

***Question 2. This workshop helped me to understand the dietary and energy needs of individuals***

| Response | Number | Percentage |
|---|---|---|
| 1. Strongly Agree | 24 | 32 |
| 2. Agree | 45 | 60 |
| 3. Neutral | 5 | 6.7 |
| 4. Disagree | 1 | 1.3 |
| 5. Strongly disagree | 0 | 0 |

***Question 3. This workshop will enable me to evaluate the nutritional information I see from other sources***

| Response | Number | Percentage |
| --- | --- | --- |
| 1. Strongly Agree | 24 | 32 |
| 2. Agree | 35 | 46.7 |
| 3. Neutral | 16 | 21.3 |
| 4. Disagree | 0 | 0 |
| 5. Strongly disagree | 0 | 0 |

The second part of the questionnaire was comprised of three open-ended questions that enabled students to express their responses individually. Many students gave multiple responses to the questions. The responses were grouped based on those addressing similar themes and then ranked in order of frequency of appearance in responses. The results from this section are expressed in terms of the total number of students who responded, the number of times the response appeared, and that appearance as a percentage of the total number of comments.

***Question 4. What did you like most about this class?***

Of the 75 questionnaires completed, 73 students responded to this question, with many identifying multiple points, giving a total of 121 responses for the question. There were six major themes for responses, listed below in order of frequency of appearance.

| Response | Number | Percentage |
| --- | --- | --- |
| Class interesting/informative/learnt something | 37 | 30.7 |
| Topic is relevant/practical for self or profession | 32 | 26.4 |
| Liked participation/group work/interactivity | 23 | 19.0 |
| Clear introduction/explanation of topic | 13 | 10.7 |
| Liked friendly/helpful/informal atmosphere | 12 | 9.9 |
| Well prepared class | 4 | 3.3 |
| | 121 | 100 |

***Question 5. What did you like least about this class?***

Of the 75 questionnaires completed, 46 students responded to this question. On the remainder of the questionnaires (29) the answer was blank or had a line drawn through it. Of the 46 respondents, 7 students responded with comments such as “no” or “nothing” or “all fine” and so were removed from this data set. Three of the remaining respondents answered with two points, therefore there was a total of 42 responses for the question. There were seven major themes for responses, listed below in order of frequency of appearance.

| Response | Number | Percentage |
|---|---|---|
| Too long - overall or between sections | 12 | 28.6 |
| Facilities/timing of class inappropriate | 9 | 21.4 |
| Explanations unclear/too short/dry topic | 8 | 19.0 |
| Didn’t like doing calculations | 6 | 14.3 |
| Recognition of own bad diet/exercise | 4 | 9.5 |
| Not all students involved | 2 | 4.8 |
| Irrelevant | 1 | 2.4 |
| | 42 | 100 |

***Question 6. Do you have any suggestions for improving this class?***

Of the 75 questionnaires completed, 39 students responded to this question. On the remainder of the questionnaires (36) the answer was blank or had a line drawn through it. Of the 39 respondents, 20 students responded with comments saying ”no” or “nothing” or “everything was good” and so were removed from this data set. Only one of the remaining respondents answered with more than one point, so there was a total of 20 responses for the question. There were three themes for responses, listed below in order of frequency of appearance.

| Response | Number | Percentage |
|---|---|---|
| Make class shorter/faster paced | 10 | 50 |
| Spend more time on explanations/examples | 5 | 25 |
| Would like some copies of food/exercise information to keep | 5 | 25 |
| | 20 | 100 |

### *Summative assessment results*

### *2003*

The metabolism laboratory classes were assessed summatively in 2003 with a single short answer question to the value of 4 marks.

The examination was sat by 164 students resulting in an average mark for this question of 1.83/4 (45.75%), with the overall average score of 43.7/66 (66.2%) for the examination. There appeared to be a bimodal distribution of scores peaking at 1/4 and 4/4 respectively (see Figure 1)

### *2004*

In 2004 the metabolism laboratory classes were assessed summatively with a single short answer question to the value of 4 marks and two multiple choice questions of 1 mark each, giving a total of 6 marks for this topic (see appendix 3). Concepts from both the Metabolism: Nutrition and Energy balance, and Metabolism: Basal metabolic rate classes were examined in these questions.

The examination was sat by 149 students. For the short answer question (Figure 1) the students achieved an average mark of 3.34/4 (83.47%), and for the multiple choice questions 1.55/2 (77.6%), giving an overall average of 81.52% for the metabolism component of the assessment. The overall average mark for the 2004 examination is not yet available.

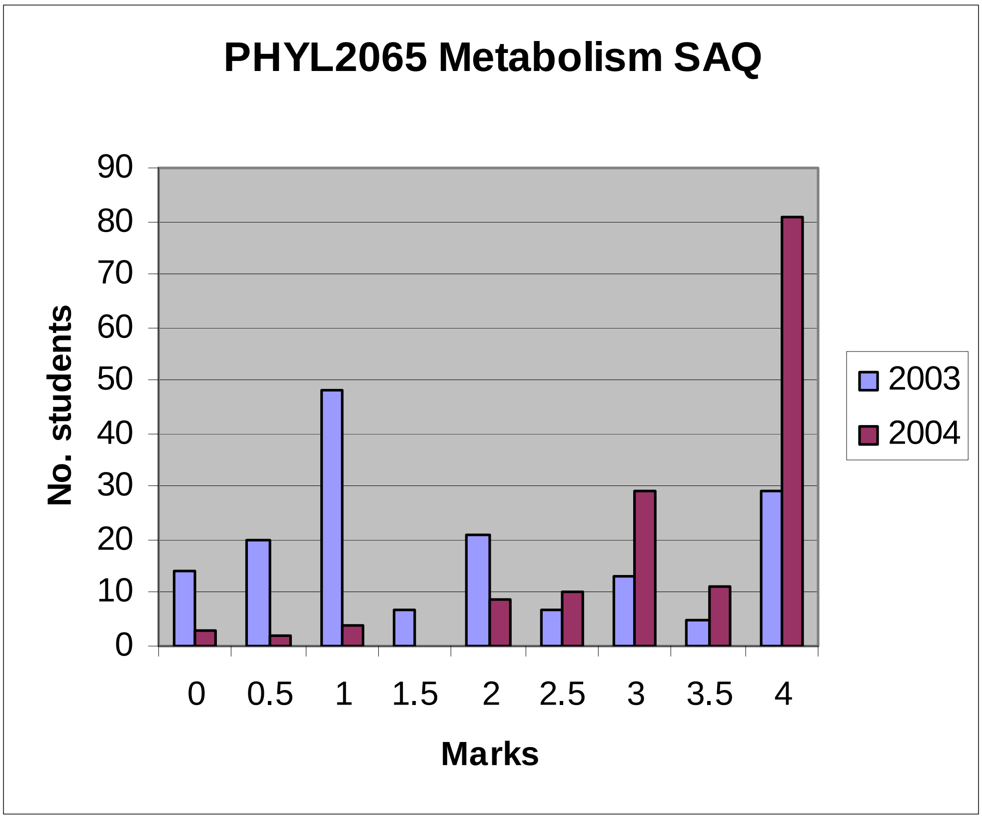


**Figure 1: Results from short-answer question assessment 2003 & 2004.**

### *Personal observations*

The room allocated for this workshop/tutorial was laid out with groups of six chairs surrounding each table. Generally group formation took place as the students entered the room by each small grouping of arrivals choosing to sit together or not and further arrivals joining already formed groups or choosing vacant tables. As the number of free tables declined students joined tables with others with whom they may not have normally worked. Some students rearranged chair groupings to better suit themselves so that group size varied from two to eight students, with the most common size being 5 students. I did not in any way rearrange groups as I had no preconceived ideas as to what was the most appropriate size.

Once the majority of students had arrived the session commenced with the students attention being directed to the introductory questions in their laboratory books. The students readily discussed their diets and exercise regimes with one another, comparing the sorts of foods they ate and quite readily discussing their perceived deficiencies. During this phase I moved about the room answering questions the students posed and informally discussed their progress. After five minutes I began a discussion on the answers with a show of hands from the students. “Who thinks their diet is good/bad/ok?” And posed further questions as to their thoughts on what constituted an optimal diet. During these two phases the students asked a number of questions of me which highlighted areas of misconception. The most common of these were “How much is the “right” amount of energy to consume?” Implying that the students fail to recognise that there is no right answer but this depends on energy expenditure, and “How much fat is too much?” again, this implies a lack of recognition of the variety of needs based on physiological state and activity level.

During the introduction I initially discussed the aims of the class and its areas of focus, and began the brief discussion on the components of food. By using an informal atmosphere I encouraged the students to ask questions during this phase, and I posed questions to the students. The students appeared alert and interested throughout the introduction and readily answered the questions posed. The final phase of the tutorial component was to discuss the information the students needed to help them assess their own energy intake and expenditure balance. The students identified the appropriate information required but appeared unfamiliar with the techniques used routinely to gain this information from individuals.

The workshop phase had been expanded to include a larger number of students as volunteers for energy expenditure and intake studies, I initially allocated 1 student per group with extra large groups doing 2 students/group. The students appeared very eager to assess more of their diet and exercise regimes and I had numerous requests from the students to do extra subjects. Due to these requests I allowed them to do as many per group as they wished and provided them with more resources.

The students were encouraged to write their findings on the whiteboard when completed, and they readily performed this task, I was interested to note they were not too reluctant even to include their bodyweight for comparison. These results then formed the basis of a class discussion, which elaborated on the implications of matching energy expenditure and intake (or not). Again the informal atmosphere encouraged student participation in the discussion.

Finally I referred the students to the questions in the laboratory book which were repeats of the early questions and asked them to reflect on their answers, particularly those that may have changed. The students did not spend as much time on this aspect as I had hoped but this may have reflected the fact that this was their last task in the workshop or that they felt their answers hadn't actually changed.

## Findings

It was particularly interesting to note that attendance at the laboratory class represented only approximately 55% of the total cohort. It is possible that some students had a strong background in nutrition and metabolism or felt they had a sufficient understanding of the topic so that they did not need to attend, but this seems unlikely to represent the remaining 45% of the students. Their attendance at laboratory classes is strongly encouraged but is not compulsory and so it is common for attendances at the laboratory classes for this course to be of this magnitude. The implications of this are that only 55% of the cohort received the intervention, and therefore there is likely to be some dilution of the benefit (or otherwise) of the intervention in regard to performance in the summative examination. Furthermore these non-attending students may represent a portion which in fact has a poor understanding of the topic or interest in it and so may actually represent a large section of the lower marks in the examination. Unfortunately there is no way to accurately identify how many students attended the class in the previous year, but it is likely that the proportions were similar. Some data which would have been of interest would be the correlation between attendance and final results, but as the surveys were anonymous there is now no way to gather this information.

Of the students that attended the class, all who completed the class also completed the questionnaire, there were just a small proportion of students who left early for various reasons, most making their excuses to me and apologising for leaving early. The results from the closed questions in the survey suggest that the majority of the students agreed that the class was beneficial, only one student – actually the same individual - disagreed in questions 1 and 2.

More than 73% of the students agreed that the class helped them to recognise their own misunderstandings, the remainder, with the exception of the one disagreeing student, were neutral. This neutral component may be interpreted as due to these students either believing that they didn't have misunderstandings or that the class had no effect. Perhaps this could have been further elucidated with an additional question on whether or not they felt they had any misunderstandings prior to the class or by more specific wording of the question itself. As discussed in the personal observations, the major misconception identified related to the lack of recognition of the influence of physiological state and activity level on energy requirements, this belief that there is a "right" amount to consume or exercise. The use of multiple individuals to compare results reinforces the physiological principles of individual variation and that energy requirements are based on individual need, and specifically addressed this misconception.

The vast majority (92%) of students also agreed that the class helped them to understand the dietary and energy needs of individuals. Only five students were neutral in this response and one student disagreed. As this was the stated aim of this class I had hoped a high percentage of students would agree and I believe this result suggests the class achieved that aim. In the final closed question nearly 79% of the students agreed that the class would assist them in evaluating diet and exercise information from other sources, none disagreed. This was not a published aim of the class, and it is not explicitly addressed during the workshop, but I did discuss it as an aim during the introduction. I believe that we are inundated with information, particularly about diet, and many “experts” give conflicting information. I consider it a very important potential benefit of this class for the students to firstly recognise that this occurs and to equip them with the knowledge to make their own judgments, based on physiological evidence, as to the quality of that information. I believe this can aid them not only personally but also professionally, as many of them will be dealing with individuals who are facing the consequences of energy intake/expenditure imbalance. Furthermore the recognition of this issue and their belief that they can address this suggests that the students are aware of, and understand the physiological principles that underlie metabolism.

The first of the open-ended questions was answered by the vast majority of students, many of whom responded with multiple points that they liked about the class. These have been grouped into major themes for ease of analysis, but it can be seen from the results that most students found the class to be informative and interesting, and they enjoyed their level of participation. Of particular note was the number of students who liked the relevance of the class to themselves and their professions.

The second and third open-ended questions dealt with the negative aspects of the class and how these might be improved. Far fewer students responded with comments to these questions than the previous question, and with very few multiple points, such that there were 42 negative comments and only 20 suggestions for improvement. More students actually responded with comments such as “everything was fine” than with negative comments. The most common negative response was that the class was too long or there was too much time between sections of the class, which seems to be based on the occasions when one or more groups took significantly longer to complete their calculations than others. It also followed then that the most common suggestion for improvement was to make the class shorter or faster paced. The next most common response related to issues outside my control, that the room was too hot or too small or the fact the class was on Friday! Indeed the day we had the largest attendance (28) was very hot and the air-conditioning did not seem to cope. There were also a small number of comments suggesting that the explanations I gave were either too short or unclear, and a couple of comments mentioning that it was a dry topic, this also related to the suggestion for improvement by spending more time on explanations and examples. A few students commented that the worst aspect was that they recognised their diet/exercise regime was inadequate – but I don’t see this as a negative, particularly if it prompts them to consider these aspects more carefully.

There was a marked improvement in the summative results for the metabolism component of the course, this was particularly obvious in the response to the short answer question, which was comparable to the question asked of the previous cohort. There was a clear shift in the curve towards higher marks with an increase in the average result from 45.8% in 2003 to 83.5% in 2004. This result clearly indicates that the learning outcomes for the students were improved by the intervention.

## Conclusions

The intervention described in this project was intended to create an environment in which the students’ were able to consider their prior knowledge to identify misconceptions, to address those misconceptions through interactive discussion and allow them to explore and integrate the information available. By this process it was intended that the students would deepen their understanding of the physiological principles that underlie metabolism, integrating the knowledge they had gained in this and other elements of their course, and allow them to develop the critical thinking skills to appraise information presented to them. The class was based on a "guided-inquiry" approach which has been shown to encourage students to be reflective and positive and increase their ability to integrate knowledge (Domin, 1999b, Berg, et al, 2003, DiPasquale, et al, 2003).

One of the important factors in developing this learning environment was the necessity to create a learning community amongst the students in which they were comfortable to discuss their knowledge and ideas openly and confidently. Working in groups, discussing their exercise and diet regimes, appeared to have achieved this. The atmosphere and format of the class encouraged them to be open and honest with one another to the extent that could openly discuss their "bad" habits and personal information like bodyweight comfortably. It was necessary for them to work cooperatively within the group, the volunteer student needed to provide the relevant information about their eating and exercise habits and other members of the group needed to cooperatively work through the information to convert it to the form needed to calculate energy intake and expenditure.

I believe this need for cooperation fostered the active participation by both volunteer and non-volunteer students that I observed, by giving all of them a role in the discussions that occurred within the groups. The informal environment of the class appeared to encourage the students to make comparisons between themselves and the volunteer students and discuss the implications of their various diet and exercise choices. It also appeared to foster camaraderie amongst the students, they recognised that they all had to deal with the same problems of time management, food selection etc.

As a teacher of this style of class I found that to encourage the students to be open and comfortable with the discussion of their personal details I too had to be comfortable with it. To demonstrate this I used a few examples from my own experience, took care to value all their input and to answer their questions in a balanced and non-judgmental manner. Ramsden (2003) emphasises that to encourage learning, students must feel part of the interaction and must not be made to feel inadequate. Furthermore, Clarke (1994) found that students, using either surface or deep approaches, felt that their learning was enhanced when they were in an environment that was interactive, supportive, and emphasised practical application. The observations of participation and cooperativeness seen in this class suggest that this environment was achieved.

In summary, the intervention performed for this project appeared to achieve the stated aims, with a clear increase in student participation and engagement and an improvement of assessment results. The intervention also appeared to produce an enhanced learning atmosphere which fostered more interaction between the students. The students expressed that they believed the class had helped them recognise their misunderstandings, improve their knowledge and their critical thinking skills. Furthermore, I observed that there appeared to be a ‘flow-on’ effect to the subsequent related class, which also seemed to have more active participation by the students than had been seen in previous years.

## Critical Reflections

I learnt a great deal through the implementation of this project, both in terms of mechanisms for applying the educational principles we discussed in the earlier components of this course, but also in the design and implementation of an evaluated project in a field of study significantly different from my prior field. With hindsight I can easily see where improvements could have been made, particularly in the evaluation, to elicit more interesting and specific data on the effectiveness of the interventions.

I have recognised the large role a teacher can play in fostering a learning community amongst the students and the care that needs to be taken to achieve the type of learning we desire in our students. These include the valuing of student input and the creation of a non-threatening environment to foster confidence and discussion amongst the students. This appears particularly important amongst students who are having difficulties with physiology – a difficult and complex topic – how important it is for them to be able to confidently discuss their ideas with one another and the teaching staff, to be able to work through the information presented to them to effectively construct their knowledge.

One of the outstanding gains of this course and project has been the development of my awareness of literature which supports and encourages change in teaching practices. This literature serves not only to justify the actions I may wish to implement but also serves as a source of many ideas for change. By putting some of those ideas into practice during this year I have recognised the potential effectiveness of what appear to be relatively minor changes in teaching practice in enhancing student learning outcomes, and how those effects can spread both amongst the student group and across the length of the course. Furthermore I have witnessed how the effects of those changes can expand into subsequent courses those students undertake. This has clearly demonstrated to me how good (or bad) teaching practice can impact on our students and emphasised the responsibility we as academics have to aim for the best possible teaching practice to improve the students experience of learning.

## References

Berg, C.A.R., Bergendahl, V.C.B. & Lundberg, B.K.S. “Benefiting from an open-ended experiment? A comparison of attitudes to, and outcomes of, an expository versus an open-inquiry version of the same experiment”. (2003) *International Journal of Science Education*, Vol 25 pg 351-372.

Bourner, J., Hughes, M. & Bourner, T. “First-year undergraduate experiences of group project work”. (2001) *Assessment & Evaluation in Higher Education*, Vol 26, pg 19-38.

Clarke, J.A. “The relationship between students’ approaches to learning and their perceptions of what helps and hinders their learning”. (1994) *Australian Association for Research in Education.* Conf. Proc 1994.

Davies, P. “Approaches to evidence-based teaching”. (2000) *Medical Teacher*, Vol 22, pg 14-21.

DiPasquale, D.M., Mason, C.L. & Kolkhorst, F.W. “Exercise in Inquiry”. (2003) *Journal of College Science Teaching*, Vol 32, pg 388-393.

Domin, D.S. “A content analysis of general chemistry laboratory manuals for evidence of higher-order cognitive tasks”. (1999a) *Journal of Chemical Education*, Vol 76, pg 109-112.

Domin, D.S. “A review of laboratory instruction styles”. (1999b) *Journal of Chemical Education*, Vol 76, pg 543-548.

McKinley, C.J. & Stoll, W.R. “A method of improving student learning in physiology: The small group workshop”. (1994) *Advances in Physiological Education*, Vol 11, pg S16-S23.

Micheal, J.A., Wenderoth, M.P., Modell, H.I., Cliff, W., Horwitz, B.A., McHale, P., Richardson, D., Silverthorn, D., Williams, S. & Whitescarver, S.A. "Undergraduates' understanding of cardiovascular phenomena". (2002*)* *Advances in Physiological Education*, Vol 26, pg 72-84.

Modell, H.I., Micheal, J.A., Adamson, T., Goldberg, J., Horwitz, B.A., Bruce, D.S., Hudson, M.L., Whitescarver, S.A. & Williams, S. "Helping Undergraduates Repair Faulty Mental Models in the Student Laboratory". (2000*) Advances in Physiological Education*, Vol 23, pg 82-90.

Ramsden, P. (2003) *Learning to Teach in Higher Education.* 2nd Ed. Routledge Falmer:London

Shiland,T.W. "Constructivism: The implications for laboratory work". (1999) *Journal of Chemical Education*, Vol 76, pg 107-109.

Wilke, R.R. "The effect of active learning on student characteristics in a human physiology course for nonmajors". (2003*) Advances in Physiological Education*, Vol 27, pg 207-223.

## Appendix 1: Laboratory book entry

# Metabolism: Nutrition & Energy Balance

### *Introduction*

This practical and the following practical - Metabolism: Basal metabolic rate - discuss the basis of metabolism in individuals. This class consists of a tutorial and workshop that looks at the utilisation of the macronutrients consumed in the diet and the energy requirements of individuals. All necessary tables will be provided. **PLEASE BRING YOUR CALCULATORS.**

### *Tutorial*

How is your diet?

Do you think your diet and your daily energy expenditure are in balance?

Which component of your diet provides the most energy?

What level of fat content do you think your diet has?

### *Nutrition*

An optimal diet that meets the nutritional requirements of the body includes: **adequate water, energy, protein, fat, vitamins and minerals**. The requirements of each person vary according to their age, gender, activity level and physiological state. Energy is required by the body to perform INTERNAL work (active transport, cell repair, etc) and EXTERNAL work (walking, lifting, etc). The energy requirements of the body are all provided by the intake of food. Energy, that is the chemical energy stored in atomic bonds of molecules, is released from the nutrient components of food by digestion. This energy is either used immediately OR stored in the body.

*Units of measurement:*

- CALORIE (amount of heat necessary to increase the temperature of 1g of water by 1°C)
- JOULE (amount of work required to move a 1g weight 1m under the force of gravity
- 1 calorie = 4.2 joules (or 1 kcal = 4.2 kJ) NB kcal often written **C**alories

The components of food that provide **energy** are the macronutrients: *carbohydrates, fats and proteins*.

#### Carbohydrates

The basic unit of carbohydrates is the simple sugar molecule, carbohydrates come in different forms: simple - monosaccharides (glucose, fructose), disaccharides (sucrose, lactose) and complex - oligosaccharides and polysaccharides (glycogen, starch and fibre eg cellulose). The main functions of carbohydrates are as an energy source, as a protein “sparer” and an aid to fat metabolism. Approximately 98% of all ingested carbohydrates can be absorbed from the GI tract. The daily requirement for carbohydrates depends on energy needs. Physiologically - 1g carbohydrate = 4 kcal / 16.8 kJ. In an “average” diet approximately 45% of energy supplied by carbohydrates.

*Glycaemic index (GI) of carbohydrates*

GI is based on the speed with which the carbohydrates are converted into glucose within the bloodstream. GI is a ranking of a food based on its effect on blood glucose compared to a standard reference food. It is influenced by the protein, fat and fibre content of food as this influences speed of digestion - high fat food can be low GI! GI appears to be particularly important for non-insulin dependent diabetics but its relevance to obesity/weight loss is still the subject of much debate.

### Fats

Fats or “lipids” exist in three main types: triglycerides, phospholipids, and cholesterol. Fats can be either saturated (generally from animal sources) or unsaturated (from vegetable sources). Body fat provides the largest store of potential energy, a protective cushion for vital organs and insulation from thermal stress of cold environments. Dietary fat is also required for the absorption of fat-soluble vitamins A, D, E and K and as a source of the essential fatty acids, linoleic and linolenic acid, which are involved in hormone production. Approximately 95% of all fat ingested can be absorbed from the GI tract. A high intake of saturated fat has been linked to heart disease and some forms of cancer. Therefore it is recommended that fat provide less than 30% of the energy requirements in the diet (NB this does not mean a diet containing 30% fat!) and more than 30% of fat intake is unsaturated fat. Physiologically 1g fat = 9 kcal/37.8 kJ. In an “average” diet, approximately 40% of energy supplied by fats.

### Proteins

Proteins consist of chains of amino acids. There are 20 different types of amino acids comprised of 8 “Essential” (can’t be synthesised by the body (9 for infants) therefore all must be present in diet) and the remaining “Non-essential” (can be synthesised by the body from other amino acids, providing there is an adequate total number of amino acids) Two classes of proteins exist: Complete, contain ratios of amino acids similar to average body protein (derived from animal products) and Partial, contain ratios of amino acids different to average body protein (derived from vegetable products). Approximately 92% of all ingested protein is absorbed from the GI tract. Proteins are broken down to their component amino acids that are then used in maintenance, repair and synthesis of body proteins. Average daily requirement is greater than 30-55g protein/day. Protein may be used as an energy source when other energy sources are lacking. On average 1g protein contains 4.35 kcal but physiologically 1g protein = 4 kcal/16.8 kJ. In an “average” diet approximately 15% of energy requirements from protein.

## *Metabolism*

Ultimately each of the macronutrients described above are broken down into their simplest forms and then transformed into adenosine triphosphate (ATP) – the form of energy used for **Metabolism** - the chemical processes that occur in the body. The amount of metabolism (energy usage) that occurs over a given time is referred to as the **Metabolic rate**. The metabolic rate has two components; the **Basal metabolic rate** (BMR) the minimum amount of energy necessary to maintain basic body function at rest, and the additional energy required to perform activities such as muscle movement and digestion.

What factors influence an individuals BMR?

What determines the additional energy usage over basal level?

## *Workshop*

1. Working in groups using either the “24-hour activity level” provided or based on one person in your group estimate the daily energy (kilojoule) expenditure of an individual.

| Activity Level | Active | Inactive | Student 1 | Student 2 | Student 3 | Student 4 | Student 5 | Student 6 |
|---|---|---|---|---|---|---|---|---|
| Energy Expended (kJ) | | | | | | | | |
| Required Energy (+5%) | | | | | | | | |

2. Use the food composition tables provided to calculate the kilojoule content and percentage of fat (using total weight and fat content) of a given diet of 3 meals for a single day (to be provided by tutor) or for your own diet over the preceding 24 hours.

| Diet | 1 | 2 | S1 | S2 | S3 | S4 |
|---|---|---|---|---|---|---|
| Total Weight (g) | | | | | | |
| Total Wt of Fat (g) | | | | | | |
| Total Energy (kJ) | | | | | | |
| Energy from Fat (Wt fat x 37.8kJ) | | | | | | |
| % Fat by Wt (Wt fat/Total Wt x 100) | | | | | | |
| % Energy from Fat (kJ fat/total kJ x 100) | | | | | | |

3. When this diet is ingested will an equivalent number of kilojoules be available to the body?

4. Why should one restrict the fat content of the diet?

5. If this diet were altered so that the components were provided entirely from vegetable sources (with the total kilojoule content remaining unchanged) what differences do you think that would make to the diet?

6. Using the food composition tables provided list at least three of the principle food sources of the following micronutrients. Try to find the three best animal and vegetable sources of each.

| Calcium | | Iron | |
|---|---|---|---|
| Animal | Vegetable | Animal | Vegetable |
| | | | |

7. Return to the questions you answered at the beginning of the practical and answer them again – have any of your perceptions changed?

How is your diet?

Do you think your diet and your daily energy expenditure are in balance?

Which component of your diet provides the most energy?

What level of fat content do you think your diet has?

## Appendix 2: Questionnaire

**PHYL2065 Nutrition Workshop Survey Form 2004**

1. This workshop helped me to recognise misunderstandings I may have had about nutrition and energy balance (circle number)

Strongly Agree — Strongly Disagree

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

2. This workshop helped me to understand the dietary and energy needs of individuals (circle number)

Strongly Agree — Strongly Disagree

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

3. This workshop will enable me to evaluate the nutritional information I see from other sources (circle number)

Strongly Agree — Strongly Disagree

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

4. What did you like most about this class?

5. What did you like least about this class?

6. Do you have any suggestions for improving this class?

Thank you for participating in this survey
Kay Colthorpe

## Appendix 3: Summative examination questions

### PHYL2065 End of semester exam: 2003

*Short answer question*
List and comment on four (4) factors that influence BASAL metabolic rate. (4 marks)

### PHYL2065 End of semester exam: 2004

*Short answer question*
You are working in a laboratory studying basal metabolic rates (BMR) of people under ideal measurement conditions. But you notice that even though the individuals in the study are the same height and weight there are still large differences between their basal metabolic rates. List four (4) factors which may account for these differences and briefly discuss how each of these factors effects BMR. (4 marks)

*Muliple choice questions (1 mark each)*
Peter and Paul are two healthy adults and both aged 18 years but Peter weighs twice as much as Paul. It is likely that at rest Peter has
A. an O\v2\v consumption less then that of Paul because the bigger the mass, the lower the metabolic rate
B. twice the O\v2\v consumption of Paul because he has twice the mass
C. a larger O\v2\v consumption rate than Paul but not as much as twice Paul's rate
D. about twice the O\v2\v consumption of Paul because he has approximately twice the surface area
E. about the same O\v2\v consumption as Paul because they are both at rest

What is a complete protein?
A. a protein that is enriched in vitamin C
B. a protein that contains none of the amino acids found in body protein
C. a protein that contains a ratio of amino acids similar to average body protein
D. a protein that provides all of the energy necessary for cell repair
E. a protein that is enriched in calcium